UNITED STATES PATENT APPLICATION FOR:

METHOD FOR ARRANGING CAMERAS AND MIRRORS TO ALLOW PANORAMIC VISUALIZATION

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METHOD FOR ARRANGING CAMERAS AND MIRRORS TO ALLOW PANORAMIC VISUALIZATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of United States provisional patent application serial number 60/419,466, filed on 10/18/2002, which is herein incorporated by reference

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to image processing. More specifically, the present invention relates to arranging cameras and reflecting surfaces in a manner that reduces parallax between neighboring fields of view while simultaneously overlapping the fields of view in a manner that enables seamless blending.

Description of the Related Art

[0003] Various methods can be used to integrate multiple cameras to enable wide-angle viewing. One subset of such methods uses optical elements, such as mirrors and prisms, in the form of reflecting surfaces to eliminate parallax between multiple cameras. The reflecting surfaces form virtual cameras that share a common principle point with a real camera or with another virtual camera. These cameras can share the same principle point while having fields of view that differ only by a rotation. Since the bore sighted cameras have the same principle point there is no parallax effect between the various cameras.

[0004] Figure 1 illustrates a bore sighted camera system 10. As shown, a first camera 12 is located so as to have a principle point 14 and a field of view 16. Also as shown, the camera system 10 includes a second camera 18 and a reflective surface 20. The reflective surface 20 interacts with the camera 18 to produce a field of view 22. That field of view corresponds to that of a virtual camera 24 that has the same

principle point 14 as camera 12. Thus, cameras 12 and 18 have respective fields of view 16 and 22 that differ only in rotation.

[0005] While bore sighted camera systems such as the camera system 10 are beneficial, in practice it can be difficult to seamlessly integrate multiple fields of view. This is at least partially because seamless blending of adjacent fields of view requires some overlap between the fields of view. However, when multiple reflecting surfaces are used to form bore sighted multiple fields of view, often there is no physical overlap between adjacent fields of view. This is illustrated in Figure 2.

[0006] Figure 2 shows a real camera 30 and three virtual cameras 32 that are formed by reflective surfaces (not shown for clarity). The cameras 30 and 32 produce four fields of view 34. However, since the fields of view 34 do not overlap blank areas 36 are created between adjacent fields of view. Those blank areas 36 make seamless integration of the fields of view very difficult or impossible. Making the task even more difficult are the interactions (border effects) between abutting mirrors or prisms and other optical defects.

[0007] Therefore, a camera system having overlapping fields of view and little parallax between adjacent camera views would be beneficial. Also beneficial would be a new method of producing overlapping fields of view using multiple cameras, but with reduced parallax and border effects.

SUMMARY OF THE INVENTION

[0008] The present invention relates to seamless blending of overlapping fields of view of multiple cameras in a manner that reduces parallax. A camera system that is in accord with the principles of the present invention can have reduced parallax and seamlessly blended fields of view.

[0009] Such a camera system includes a first camera having a first principle point and a first field of view, a second camera, and an optical element that produces a virtual image of the second camera such that the virtual image has a second principle point and a second field of view. The first and second principle points are separated, while the first and said second fields of view overlap. If the camera system includes

more than two cameras, the individual virtual camera principle points are beneficially located on a geometric curve such as a circle.

[0010] The first and second principle points should be close enough that the parallax of the cameras is less than a predetermined maximum allowable parallax, but far enough apart that the fields of view overlap enough to enable seamless blending of the fields of view. Beneficially, the optical element has a reflecting surface. Thus, suitable optical elements include mirrors and prisms.

[0011] The principles of the present invention further provide for a method of imaging. Such a method includes imaging a first field of view from a first principle point, and imaging a second field of view from a second principle point that is close to, but separated from, the first principle point, but such that the first and second fields of view overlap. In the method of imaging, the second field of view is produced by a reflection, and the first and second principle points are close enough to reduce the imaging parallax below a predetermined maximum allowable parallax. Additionally, the first and second principle points are beneficially far enough apart that the first and second fields of view overlap such that seamless blending of the fields is possible.

[0012] The present invention will find use in numerous applications such as vehicle imaging systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that the manner in which the above recited features of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

[0014] It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0015] Figure 1 is a top down view of a bore sighted multiple camera system;

[0016] Figure 2 is top down view of a bore sighted multiple camera system having blank areas between fields of view;

[0017] Figure 3 illustrates a multiple camera system that is in accord with the principles of the present invention;

[0018] Figure 4 illustrates a panoramic viewing system mounted on a tank; and

[0019] Figure 5 illustrates a camera system having cameras and prisms and that implement the principles of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0020] The principles of the present invention enable multiple camera systems having reduced parallax and overlapping fields of view that allow seamless blending of the fields of view. According to the present invention, cameras and reflective surfaces are arranged such that the resulting virtual camera principle points lie in a plane a small distance from a point, thus differing from camera systems that have one principle point.

[0021] Figure 3 illustrates an embodiment of the present invention. As shown, a principle point 50 of a real camera 52, and the principle points 54 of virtual cameras 56 are all located a distance away from a center 58. By placing the principle points 50 and 54 away from the center 58 the physics of the reflecting surfaces can increase the fields of view 60 such that the fields of view overlap. This overlap is very beneficial for seamlessly blending the fields of view 60 together.

[0022] The distance between the principle points (50 and 54) and the center 58 is task dependent. Note that Figure 3 shows the principle points on the locus of a circle. The radius of that circle should be based on the maximum allowable parallax between the neighboring fields of view. That maximum controls the maximum radius M of the circle. The radius of the circle should also be based on the amount of overlap required for seamless blending. That amount controls the minimum radius S of the circle. Thus, the circle should have a radius of R, where $S < R < M$.

[0023] In Figure 3 the cameras are illustrated as looking outward in a common plane. While such a coplanar arrangement is usefully illustrative of the invention herein described, the cameras can also usefully point upward or downward from the indicated plane.

[0024] It should be noted that the principle points do not have to be placed on the locus of a circle. Some applications may benefit by locating the principle points on a hyperbole, on a parabola, or on another geometric figure such as a bezier curve.

[0025] It should also be noted that various seamless blending techniques can be applied to the present invention. The present invention is not limited to a particular blending technique. For example, the blending technique can be implemented such that a particular field of view is selected over another field of view at the overlapped region. Alternatively, a more complicated blending operation can be performed at the overlapped region.

[0026] The present invention can be used on moving vehicles such as armored military or security vehicles. For example, Figure 4 illustrates a tank 400 having a parallax corrected camera assembly 402 that is mounted on a tank body 404. As shown in Figure 5, the camera assembly 402 is comprised of prisms 504 that are mounted on a housing 506. Inside the housing is a plurality of camera cameras 12. The cameras image through the prisms 504, which act as mirrors 20 (see Figure 1).The camera assembly 402 is configured such that neighboring cameras have overlapping the fields of view as schematically illustrated in Figure 3.

[0027] While the foregoing is directed to the preferred embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.